

PROCESS FOR PRODUCING SPIRAL MEMBRANE ELEMENT

FIELD OF THE INVENTION

The present invention relates to a process for producing a spiral membrane element for separating a specific ingredient from various fluids (liquids or gases). More particularly, the invention relates to an improved method of creasing a membrane for use in spiral membrane elements.

DESCRIPTION OF THE RELATED ART

Conventional spiral membrane elements are known to have a structure obtained by disposing a permeation-side passage material to the permeation side of two membranes, sealing three sides of the membranes to form a layered product of a bag shape, connecting a set of such layered products (membrane leaves) to a perforated core tube, and spirally winding the connected layered products together with feed-side passage materials interposed therebetween. An element is also known which employs two or more sets of such layered products (membrane leaves) so as to reduce the permeation-side passage length.

The basic structure of the latter element generally comprises a perforated core tube and spirally wound thereon a multilayer structure including a feed-side passage material interposed between opposed membranes on their feed side and a permeation-side passage material interposed between opposed membranes on their permeation side and further has a sealing structure for preventing the feed-side passages from being directly connected to the permeation-side passages. More specifically, an element is already known which comprises a perforated core tube and wound therearound either a membrane assembly composed of a twice-folded membrane leaf comprising membranes and a feed-side passage material sandwiched therebetween on their separating layer side and a permeation-side passage material disposed adjacently to the membrane leaf or a multilayer structure comprising two or more such membrane

assemblies (see, for example, U.S. Patent 3,417,870 (page 1, Fig. 2)).

The following method is employed as a process for producing such a spiral membrane element, as shown in Fig. 6 (a) to (c). First, a membrane leaf 3 comprising a folded membrane 1 and a feed-side passage material 2 is superposed on a permeation-side passage material 4. Membrane assemblies each obtained in this manner are stacked so as to shift the respective positions of the assemblies at a given interval (the length obtained by dividing the length of the periphery of a core tube 5 by the number of the membrane leaves 3) to produce a multilayer structure. Subsequently, the multilayer structure is wound on the core tube 5. Although Fig. 6 illustrates an example having a constitution in which the membrane leaves 3 are independent and discontinuous (independent leaves), a constitution is also known in which the membranes 1 of the respective membrane leaves 3 are continuous.

In the production method described above, it is necessary in membrane leaf production to fold the membrane precisely at a right angle to the winding direction so as to avoid positional shifting and wrinkling. In this operation, since folding the membrane alone is apt to cause a defect to the membrane at the resultant crease, the membrane is protected by applying a pressure-sensitive adhesive tape to each part to be creased. The membrane in this state is folded up at a right angle by a method comprising folding the membrane and squeezing the folded parts by hand or with a plastic plate, roller, or the like to form creases.

A method is known in which a line or broken line is formed beforehand in a separating membrane in order to improve the precision of crease straightness and perpendicularity (see, for example, JP-A-10-137559 (page 1, Fig. 2)). A method is also known in which creases are formed with heating (see, for example, U.S. Patent 5,681,467 (column 5)).

However, the method which includes mere formation of a line or broken line has had a drawback that creases are not sufficiently formed and this is apt to cause

distortion in the later step of winding or the like, resulting in "wrinkling" or "breakage". The method which includes mere heating has had the following drawbacks. The precision of crease straightness or perpendicularity is poor. Furthermore, since heating to high temperature (350-420 K (77-147°C)) is necessary for forming sufficient creases, the creased parts undergo thermal shrinkage and this distortion causes "wrinkling" or "breakage" or results in holes in the membrane.

SUMMARY OF THE INVENTION

Accordingly, an object of the invention is to provide a process for spiral membrane element production in which creases are stably and sufficiently formed to thereby enable the later step of winding or the like to be smoothly conducted while eliminating the "wrinkling" or "breakage" caused by the distortion of creased parts.

As a result of intensive investigations, it has been found that the object can be accomplished by forming a folding initiation part beforehand in a membrane along each of folding lines for the membrane and folding the membrane at these parts with heating and pressing. The invention has been achieved based on this finding.

The invention provides a process for producing a spiral membrane element which comprises: the step of forming a multilayer structure comprising a membrane which has been folded, a feed-side passage material disposed on the feed side of the folded membrane, and a permeation-side passage material disposed on the permeation side of the folded membrane; the step of spirally winding at least the multilayer structure on a perforated core tube; and the step of forming a sealing structure for preventing the feed-side passages from being directly connected to the permeation-side passages, the folded membrane being obtained by forming beforehand in a membrane a folding initiation part reduced in bending resistance along each of folding lines for the membrane, folding the membrane at the folding initiation parts, and heating and pressing the membrane during and/or after the folding.

In this process, the multilayer structure preferably comprises a continuous

membrane which has been pleated, a feed-side passage material disposed on the feed side of the membrane, and a permeation-side passage material disposed on the permeation side of the membrane, in which the folding initiation part has been formed only in each folding part where the feed-side passage material is to be sandwiched.

According to the invention, creases can be formed with satisfactory precision of straightness and perpendicularity because folding initiation parts are formed prior to folding. The "wrinkling" and "breakage" attributable to the distortion of creased parts can hence be eliminated. Furthermore, since the membrane is heated and pressed during and/or after the membrane folding, the creased parts are inhibited from swelling and being thus distorted, whereby stable and sufficient creases can be formed. As a result, the later step of winding or the like can be smoothly carried out. In addition, since the folding initiation parts have a reduced bending resistance, it is possible to lower the degree of heating and pressing (alleviate the heating/pressing conditions) and thereby enable the membrane to be less damaged as compared with the case where no folding initiation part is formed.

When the multilayer structure comprises a continuous membrane which has been pleated, a feed-side passage material disposed on the feed side of the membrane, and a permeation-side passage material disposed on the permeation side of the membrane, and when the folding initiation part has been formed only in each folding part where the feed-side passage material is to be sandwiched, then there is no need of sealing the winding termination side parts because the membrane is continuous. Furthermore, since no folding initiation part is formed in the winding termination side parts, the membrane can be made to have folding parts in appropriate positions according to the wound state. The winding termination side parts can hence be inhibited from being distorted.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is views diagrammatically illustrating steps of one embodiment of the

process for spiral membrane element production of the invention.

Fig. 2 is views illustrating, in more detail, part of a step shown in Fig. 1.

Fig. 3 is views illustrating, in more detail, part of the step shown in Fig. 1.

Fig. 4 is views illustrating, in more detail, part of the step shown in Fig. 1.

Fig. 5 is a view diagrammatically illustrating one embodiment of the process for spiral membrane element production of the invention.

Fig. 6 is views diagrammatically illustrating one example of a process for spiral membrane element production heretofore in use.

In the drawings:

- 1 membrane
- 2 feed-side passage material
- 4 permeation-side passage material
- 5 core tube
- 10 porous sheet
- 21 mold
- 22 edged tool
- 23 hot plate
- L1 folding line
- L2 folding initiation part
- S1 multilayered object
- S2 multilayer structure
- R1 wound structure

The embodiment of the invention will be explained below by reference to drawings. Fig. 1 (a) to Fig. 5 (b) are diagrammatic views illustrating steps of one embodiment of the process for spiral membrane element production of the invention.

The process of the invention includes the step of forming a multilayer structure S2 comprising a membrane 1 which has been folded, a feed-side passage material 2

disposed on the feed side of the folded membrane 1, and a permeation-side passage material 4 disposed on the permeation side of the folded membrane 1, as shown in Fig. 1 (b). In this embodiment, the step of forming a multilayer structure S2 comprises a step in which permeation-side passage materials 4 are fixed each at an end thereof to a porous sheet 10 at a given interval and a step in which a pleated continuous membrane 1 and feed-side passage materials 2 sandwiched therebetween are inserted between the fixed permeation-side passage materials 4 to thereby form the multilayer structure S2, as shown in Fig. 1 (a) and (b). In this embodiment, the core tube 5 serves as a permeation-side passage (e.g., water-collecting core tube).

The feed-side passage materials 2 used can be any of conventional feed-side passage materials for use in spiral membrane elements. Specifically, any of nets, meshes, woven filament fabrics, woven fiber fabrics, nonwoven fabrics, grooved sheets, corrugated sheets, and the like can be used. Such feed-side passage materials may be made of a resin such as polypropylene, polyethylene, poly(ethylene terephthalate) (PET), polyamide, or the like or any of natural polymers, rubbers, metals, and the like. However, in the case where dissolution from the passage materials may pose a problem in a separation operation or the like, it is preferred to take account of this dissolution in selecting a material.

The thickness of each feed-side passage material 2 is preferably from 0.3 mm to 2 mm. The feed-side passage materials 2 preferably have a thickness-direction porosity of from 10% to 95%. In the case where each feed-side passage material 2 is a net, it preferably has a pitch of from 0.5 mm to 10 mm.

The permeation-side passage materials 4 used can be any of known permeation-side passage materials for spiral membrane elements. Specifically, any of nets, meshes, woven filament fabrics, woven fiber fabrics, nonwoven fabrics, grooved sheets, corrugated sheets, and the like can be used. Such permeation-side passage materials may be made of a resin such as polypropylene, polyethylene, poly(ethylene

terephthalate) (PET), polyamide, epoxy, urethane, or the like or any of natural polymers, rubbers, metals, and the like. However, in the case where dissolution from the passage materials may pose a problem in a separation operation or the like, it is preferred to take account of this dissolution in selecting a material.

The thickness of each permeation-side passage material 4 is preferably from 0.1 mm to 2 mm. The permeation-side passage materials 4 preferably have a thickness-direction porosity of from 10% to 80%. In the case where each permeation-side passage material 4 is a net, it preferably has a pitch of from 0.3 mm to 5 mm.

The porous sheet 10 may be any sheet which is permeable to fluids at least in some degree. Any of the permeation-side passage materials 4 which satisfy this requirement can be used. Preferred examples of the form of the porous sheet 10 include net, mesh, woven filament fabric, and the like. The percentage of openings or porosity of the porous sheet 10 is preferably from 10 to 80%, more preferably from 40 to 80%. In the case where passage materials are to be fixed to the porous sheet 10 by thermal fusion bonding or ultrasonic fusion bonding, it is preferred that the passage materials and porous sheet 10 selected should be made of the same material or be fusion-bondable materials.

Besides thermal fusion bonding and ultrasonic fusion bonding, examples of methods for the fixing include bonding with an adhesive, bonding with a pressure-sensitive adhesive tape or a material for thermal fusion bonding, and mechanical connection by suture or with staples or the like. Any of these may be used. An overlap width may be taken for the fixing. The parallelism between the permeation-side passage materials 4 in the fixing is preferably from 0.01 to 1 degree, and the parallelism with the core tube 5 is preferably from 0.01 to 1 degree.

Even when passage materials are fixed to a porous sheet 10 at different intervals, the intervals can be corrected, for example, by regulating the positioning of membranes,

etc. However, it is preferred to fix passage materials at almost the same interval. In the case where passage materials are to be fixed at almost the same interval, this interval preferably is the length obtained by dividing the length of the periphery of the core tube 5 by the number of the passage materials to be fixed.

In this embodiment, the porous sheet 10 is partly fixed beforehand to the core tube 5 as shown in Fig. 1 (a). This step may be conducted at any stage before the porous sheet 10 and other members are wound on the core tube 5. For example, this step may be conducted before or immediately after the fixing of the passage materials to the porous sheet 10 or just before the porous sheet 10 and other members are wound on the core tube 5.

The core tube 5 used can be any of known core tubes. For example, a perforated core tube made of a metal, fiber-reinforced plastic, plastic, ceramic, or the like may be used. The shape, size, positions, and number of holes each may be any of known ones according to the kind of the membranes, etc.

The outer diameter and length of the core tube 5 are suitably determined according to the size of the spiral membrane element. For example, the core tube 5 has an outer diameter of from 10 to 100 mm and a length of from 500 to 2,000 mm, and preferably has an outer diameter of from 12 to 38 mm and a length of from 900 to 1,200 mm.

Besides thermal fusion bonding and ultrasonic fusion bonding, examples of methods for fixing the porous sheet 10 to the core tube 5 include bonding with an adhesive, bonding with a pressure-sensitive adhesive tape, double-faced pressure-sensitive adhesive tape, or material for thermal fusion bonding, and mechanical fixing. Any of these may be used. The part to be fixed is not particularly limited as long as the porous sheet 10 is fixed at least partly. It is, however, preferred that an end of the porous sheet 10 be fixed throughout the whole length of the end side, from the standpoint of satisfactorily conducting the winding step. It is possible to

wind the porous sheet 10 beforehand on the core tube 5 to make from 1 to 10 laps, preferably from 1 to 3 laps.

Subsequently, as shown in Fig. 1 (b), a membrane 1 and feed-side passage materials 2 are inserted between the permeation-side passage materials 4 fixed to the porous sheet 10. Thus, a multilayer structure S2 is formed. In this embodiment, for the insertion of the membrane 1 and the feed-side passage materials 2, a multilayered object S1 is prepared beforehand which comprises a pleated continuous membrane and feed-side passage materials 2 disposed beforehand on the feed side of the membrane.

The membrane to be used in the invention is not particularly limited as long as it is a porous membrane or nonporous membrane having a pressure loss in permeation not lower than a given level. Examples thereof include microfiltration membranes, ultrafiltration membranes, nanofiltration membranes, reverse osmosis membranes, ion-exchange membranes, gas permeation membranes, and dialysis membranes. As the material of the membrane can be used a polymer such as a polyolefin, e.g., polypropylene or polyethylene, polysulfone, polyethersulfone, polystyrene, polyacrylonitrile, cellulose acetate, polyamide, polyimide, or fluororesin.

The multilayered object S1 described above can be produced, for example, by the method illustrated in Fig. 2 (a) to Fig. 4 (b). First, as shown in Fig. 2 (a), both side edges of a membrane 1 which is a continuous membrane are partly fusion-bonded thermally (densified) to form fusion-bonded parts 1a in order to heighten the sealability of both edge parts of the membrane 1. As the continuous membrane is used, e.g., one having a width of from 500 to 2,000 mm, preferably from 900 to 1,200 mm. In this case, thermal fusion bonding (heat sealing, ultrasonic welding, or the like) is continuously conducted over a width of up to 50 mm in a region of 100 mm from each edge while unwinding the continuous membrane from a roll. Preferably, thermal fusion bonding is conducted over a width of up to 30 mm in a region of 30 mm from each edge.

As shown in Fig. 2 (b), a fusion-bondable tape 11 having a width of from 5 to 100 mm is applied to the edge of the permeation side of each fusion-bonded part 1a at a pressure of from 0.01 to 1 MPa while avoiding wrinkling. Preferably, the tape is applied over a width of from 5 to 30 mm from each edge at a pressure of from 0.01 to 0.5 MPa. The fusion-bondable tape 11 may be one comprising a fusion-bondable base tape and a pressure-sensitive adhesive layer formed thereon. It may also be one having no pressure-sensitive adhesive layer.

As shown in Fig. 2 (c), a pressure-sensitive adhesive tape 12 for reinforcement which has a width of from 10 to 100 mm is applied to the feed side of the membrane at the same interval of from 500 to 2,000 mm in the length direction while avoiding wrinkling in the width direction. Preferably, a pressure-sensitive adhesive tape 12 having a width of from 10 to 50 mm is applied at the same interval of from 500 to 1,500 mm in the length direction. The pressure-sensitive adhesive tape 12 may be any of PET tapes and the like. The areas where the adhesive tape 12 is applied are the parts to be turned down or turned up when the membrane is continuously folded.

In the invention, the membrane 1 is folded in the following manner as shown in Fig. 3 (a) and (b). A folding initiation part L2 reduced in bending resistance is formed beforehand along each folding line L1 for the membrane 1. This membrane 1 is folded at these folding initiation parts L2, and is heated and pressed during and/or after this folding. Although this heating/pressing may be conducted during the folding, or after the folding, or during and after the folding, it is preferred to maintain a heated and pressed state for a certain time period after the folding.

For forming the folding initiation part L2, any method capable of forming a part reduced in bending resistance along each folding line L1 can be used. In the case of using a pressure-sensitive adhesive tape 12 or the like, to reduce the bending resistance of at least one of the membrane 1 and the pressure-sensitive adhesive tape 12 suffices. Examples of the shape of the folding initiation part L2 include lines and broken lines

which each are a groove or crease or in a densified state.

Specific examples of methods for forming the folding initiation part include a method in which as shown in Fig. 3 (a), the membrane is placed on, e.g., a grooved mold 21, grooved roll, or pair of rolls as a receiving tool and an edged tool 22 or rotary blade which forms a straight line or broken line is pressed from above against the membrane to sandwich it. The width of the line is, for example, from 0.1 to 10 mm, preferably from 0.1 to 3 mm. The load to be applied for the pressing is, for example, from 1 to 500 N, preferably from 1 to 200 N.

As shown in Fig. 4 (a), feed-side passage materials 2 having a width of, for example, from 500 to 2,000 mm, preferably from 900 to 1,200 mm, which have been cut into a length of from 500 to 2,000 mm are fixed alternately to the parts to which the pressure-sensitive adhesive tape 12 has been applied. Examples of methods for this fixing include thermal fusion bonding, stapling, and fixing with a tape or resin. However, ultrasonic welding is preferred.

As shown in Fig. 4 (b), each part to which the pressure-sensitive adhesive tape 12 having a feed-side passage material 2 fixed thereto has been applied is folded at nearly the center thereof (i.e., at the folding line L1) so that the feed-side passage material 2 is located inside. The membrane is thus folded over a length corresponding to the predetermined number of leaves to thereby form a multilayered object S1. This folding can be conducted by hand, with a jig, or by an apparatus which automatically performs this operation. The predetermined number of leaves is, for example, from 3 to 40.

In the folding operation described above, the parts to which the feed-side passage materials 2 have not been attached are kept in an uncreased state. Namely, the folding initiation part L2 is formed only in each folding part where a feed-side passage material 2 is to be sandwiched. In this stage, the membrane 1 is creased only at the folding initiation parts L2.

For the purposes of stabilizing the creased parts thus formed and improving the shape retention and strength thereof, the membrane 1 is heated and pressed during and/or after the folding thereof. Examples of methods for this heating/pressing include: a method in which each folded part is sandwiched between a pair of hot plates 23 as shown in Fig. 3 (b); a method in which each folded part is passed through the nip between a pair of heated rolls; and a method in which each folded part is pushed into a heater having a space capable of holding the folded part therein.

With respect to specific conditions for the heating/pressing, it is preferred to conduct hot pressing for from 1 to 300 seconds at a temperature of from 30 to 80°C and an air pressure of from 0.01 to 0.6 MPa (this pressure corresponds to about 1 N/cm in terms of force per unit length of the creased part). More preferably, hot pressing is conducted at a temperature of from 40 to 70°C and an air pressure of from 0.01 to 0.5 MPa for from 1 to 120 seconds. This operation is thus conducted at a lower temperature than in heating/pressing techniques heretofore in use. Consequently, the material can be inhibited from suffering thermal shrinkage or distortion and from thermally undergoing a change in composition, etc.

As shown in Fig. 1 (b), this multilayered object S1 is inserted between the permeation-side passage materials 4 fixed to the porous sheet 10. This insertion may be accomplished, for example, by placing the permeation-side passage materials 4 and the leaves respectively on both sides of a plane and alternately superposing these one after another. This step can be automated. Also usable is a method in which permeation-side passage materials 4 are successively interposed when a folding step such as that shown in Fig. 4 (b) is conducted.

In this embodiment, after the multilayered object S1 is inserted to form a multilayer structure S2, the fusion-bondable tapes 11 are used to fix the membrane 1 to those parts of the porous sheet 10 which are located close to the membrane 1, as shown in Fig. 1 (c). This fixing is conducted over a length corresponding to the

predetermined number of leaves. Besides thermal or ultrasonic fusion bonding with the fusion-bondable tapes 11, examples of methods for the fixing include bonding with an adhesive and bonding with a pressure-sensitive adhesive tape, double-faced pressure-sensitive adhesive tape, or material for thermal fusion bonding. Any of these methods may be used. The precision of this operation is preferably such that the parallelism with the permeation-side passage materials 4 is from 0.01 to 1 degree and the parallelism with the core tube 5 is from 0.01 to 1 degree.

The process of the invention includes the step of spirally winding at least this multilayer structure S2 on the perforated core tube 5 as shown in Fig. 1 (d). For this winding step, a method may be used in which the multilayer structure S2 is wound while applying a tension to the porous sheet 10. It is, however, preferred to conduct the winding by rotating the core tube 5 while pressing one or more rolls 15 against the periphery of the wound structure R1 as shown in Fig. 5 (a).

For rotating the core tube 5, an existing winding apparatus can be used. The core tube 5 is attached to the winding chuck and rotated. The rotational speed is, for example, from 10 mm/min to 50 m/min in terms of the peripheral speed of the wound structure R1. The torque for the rotation is not particularly limited as long as the core tube 5 can be rotated.

In the operation described above, the rolls 15 may be either free-rotating ones or ones having a rotation-breaking force or driving force. It is, however, preferred to employ rolls which are free-rotating or have a slight breaking force. The pressure at which the rolls 15 are pressed against the wound structure R1 may be about from 0.01 to 0.7 MPa, preferably from 0.01 to 0.5 MPa, in terms of the pressure of air supplied, under general conditions in air cylinder pressing. That air pressure range corresponds to linear pressures ranging from 0.75 to 3.7 N/cm.

In the invention, the winding step described above may be conducted to wind the multilayer structure S2 to the final stage. However, a step may be conducted in

which during or after completion of the winding, the wound structure R1 is tightened by rotating the core tube 5 while pressing the one or more rolls 15 against the wound structure R1 at a higher pressure. In the case of continuous leaves as in this embodiment, it is possible to provisionally crease the peripheral side of each leaf by conducting the winding up to the final stage. In the tightening step, the state of being tightened can be regulated by controlling the pressure and speed.

It is preferred in the invention that a sheathing sheet 16 be wound on the wound structure R1 after the winding. This operation can be conducted by a method in which the rolls 15 are released and a sheathing sheet 16 is then wound while applying a tension, as shown in Fig. 5 (b). Alternatively, a method can be used in which during or after completion of the tightening step, a sheathing sheet 16 is wound while pressing one or more rolls 15 against the wound structure.

The sheathing sheet 16 preferably is, for example, a tape having a pressure-sensitive adhesive layer or a sheet having adhesiveness. The sheathing sheet 16 is wound to make, for example, from 1 to 200 laps to thereby improve the degree of tightening. Preferably, the sheathing sheet 16 is wound to make from 1 to 50 laps.

In the invention, the step of forming a sealing structure for preventing the feed-side passages from being directly connected to the permeation-side passages is conducted, for example, in the same manner as in a technique heretofore in use. This step may be conducted in any stage and may be conducted in two or more steps. Examples thereof include: a step in which the fusion-bondable tapes 11 are used to seal both edges of the membrane 1, with the permeation-side passage materials 4 being interposed between opposed parts of the membrane 1 on their permeation side; a step in which those parts of both edges of the membrane 1 which are located close to the porous sheet 10 are sealed; and a step in which when not a continuous membrane but leaves are used, the outer edges of the membranes 1 are sealed.

Besides thermal or ultrasonic fusion bonding with the fusion-bondable tapes 11,

examples of methods for the sealing include bonding with an adhesive and bonding with a pressure-sensitive adhesive tape, double-faced pressure-sensitive adhesive tape, or material for thermal fusion bonding. Any of these may be used.

After the winding, the wound structure may be heat-treated at an appropriate temperature in order to remove the residual stress from the parts sealed by, e.g., thermal fusion bonding. Alternatively, the winding step may be conducted with, e.g., heating at a temperature which does not separate the parts bonded by, e.g., thermal fusion bonding. It is also possible to wind a peripheral-part passage material such as, e.g., a net around the periphery of the membrane 1 after the winding step.

Other embodiments are described below.

(1) In the embodiment described above, a reinforcement such as a pressure-sensitive adhesive tape is applied to the folding parts of the membrane. However, in such cases where a membrane having a sufficient strength is used, the membrane alone may be folded without using a reinforcement. Use of a reinforcement such as a pressure-sensitive adhesive tape is effective especially when folding initiation parts are formed by forming broken lines. It is also possible to use a method in which a folding initiation part is formed beforehand in a reinforcement to be used and this reinforcement is applied or otherwise bonded to a membrane to thereby form a folding initiation part reduced in bending resistance along each of folding lines for the membrane.

(2) In the embodiment described above, the multilayer structure includes a pleated continuous membrane which has folding initiation parts formed only in the folding parts (winding initiation side) where feed-side passage materials are to be sandwiched. However, it is possible to form folding initiation parts also in the folding parts (winding termination side) where permeation-side passage materials are to be sandwiched. In this case, it is preferred from the standpoint of preventing positional shifting to seal beforehand both edges of the continuous membrane before the

multilayer structure is wound.

(3) In the embodiment described above, permeation-side passage materials are fixed to a porous sheet so as to utilize a core tube as a permeation-side passage. However, in such cases where cake formation or the like due to concentration polarization is not problematic, feed-side passage materials may be fixed to a porous sheet so as to utilize a core tube as a feed-side passage.

(4) In the embodiment described above, a multilayered object comprising a pleated continuous membrane and feed-side passage materials disposed beforehand on the feed side of the membrane is prepared beforehand and this multilayered object is inserted between permeation-side passage materials. However, a method may be used in which a continuous membrane is first inserted between permeation-side passage materials and then feed-side passage materials are inserted between opposed parts of the continuous membrane.

(5) In the embodiment described above, permeation-side passage materials are fixed beforehand to a porous sheet and wound using the porous sheet. However, a method may be used in which permeation-side passage materials are directly fixed to a core tube by, e.g., ultrasonic fusion bonding and the core tube is then rotated to wind the multilayer structure.

(6) In the embodiment described above, a multilayer structure comprising continuous leaves formed from a continuous membrane is wound. In the invention, however, a method may be used in which two or more independent leaves prepared beforehand are used to form a multilayer structure and this structure is wound on a core tube. It is also possible to wind only one long leaf on a core tube.

The present invention will be described in more detail by reference to the following Examples, but it should be understood that the invention is not construed as being limited thereto.

EXAMPLE 1

A 924 mm-wide membrane (NTR-759HR) manufactured by Nitto Denko Corp. was unwound and, simultaneously therewith, 5 mm heat sealing was continuously conducted in a width of 10 mm from each side edge. A fusion-bondable tape having a width of 20 mm was applied to the edge of the permeation side of each fusion-bonded part at a pressure of 0.05 MPa while avoiding wrinkling. It was ascertained that no wrinkles were formed. A PET tape NO. 31B having a width of 50 mm (manufactured by Nitto Denko Corp.) was applied to the feed side of the membrane at the same interval of 750 mm in the length direction while avoiding wrinkling. After the tape application, a metallic edged tool having a width of 0.5 mm and a mold as a receiving tool were used to form a line at a pressure of 200 N in each part to be creased. A feed-side passage material made of PP and having a width of 924 mm was cut into 750 mm beforehand. The cut feed-side passage materials were fixed alternately to the parts to which the PET tape had been applied. This fixing was conducted with an ultrasonic welder. The passage materials were ascertained to be satisfactorily adhered. Each part to which the PET tape having a feed-side passage material fixed thereto had been applied was creased at nearly the center thereof so that the feed-side passage material was located inside. The membrane was thus folded over a length corresponding to the predetermining number of leaves which was 32. In the multilayered object thus obtained, the parts to which the feed-side passage materials had not been attached remained uncreased. For the purpose of increasing the strength of the creased parts, hot pressing was conducted for 2 seconds at 70°C and an air pressure of 0.5 MPa. This multilayered object was prepared beforehand as a product to be mounted. It was ascertained that the membrane could be precisely creased along the lines perpendicularly formed, without swelling or being distorted.

On the other hand, a permeation-side passage material made of PET and having a width of 884 mm and a length of 750 mm was attached with ultrasonic to a core tube

made of a noryl resin and having an outer diameter of 38 mm and a length of 1,016 mm. The passage material was ascertained to have been satisfactorily attached. This passage material was wound on the core tube so as to make one lap. Subsequently, 884-mm permeation-side passage materials which had been cut in a separate step were fixed by thermal fusion bonding to the attached permeation-side passage material at almost the same interval over the length of the periphery of the core tube. The number of these passage materials thus fixed corresponded to the predetermined number of leaves, which was 32. The parallelism between the permeation-side passage materials was ascertained to be 0.01 degree, and the parallelism with the core tube was ascertained to be 0.01 degree.

The multilayered object described above was attached to the thus-obtained permeation-side passage material assembly by thermally fusion-bonding the hot-pressed edges of the leaves of the multilayered object, one by one, to the respective permeation-side passage materials. Thus, the leaves were attached in the predetermined number of 32. The precision of this operation was ascertained to be such that the parallelism with the permeation-side passage materials was 0.01 degree and the parallelism with the core tube was 0.01 degree. The core tube of the resultant assembly was set on a winding chuck. This chuck was wound at a constant speed (20 m/min). In this operation, rolls were pressed from two directions against the element at a constant pressure (air supply pressure, 0.01 MPa) to make the sides even. The edges on the periphery side were provisionally creased. After 30 rotations, another roll was further applied to tighten the element. In this operation, the element was wrapped by winding a tape thereon to make 20 laps. As a result, the degree of tightening was further improved. The winding operation was completely free from wrinkling, breakage, and positional shifting, and the desired performances were obtained.

It should further be apparent to those skilled in the art that various changes in form and detail of the invention as shown and described above may be made. It is

intended that such changes be included within the spirit and scope of the claims appended hereto.

This application is based on Japanese Patent Application No. 2002-374827 filed December 25, 2002, the disclosure of which is incorporated herein by reference in its entirety.